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DEVELOPMENT OF A DEEP-SEA CUSHION STAR, *PTERASTER TESSELATUS*

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Abstract: The breeding season of *Pteraster tesselatus* Ives in the vicinity of San Juan Island, Washington, is around July and August. Under laboratory conditions, the development from fertilization to the completion of metamorphosis takes about a month. The animal does not brood its young; the larva is pelagic but no functional digestive tract is developed throughout the larval life.

Pteraster tesselatus Ives, commonly known as a cushion star, belongs to the order Spinulosa and family Pterasteridae. It is a deep-sea form ranging from 8 to 238 fathoms on various kinds of sea bottom from the Bering Sea south along the North American coast to Washington (Fisher, 1911). Special features of this sea star are the supradorsal membrane with a central osculum which is directly connected with the respiratory system, and the upward extension of the ambulacral groove at the end of the arms (fig. 1). Verrill (1914) commented about the family in general as follows: "This is one of the most peculiar groups of starfishes hitherto discovered. It shows, in general characters, a remarkably high degree of specialization not found in any other group."

This animal has been known for a long time as a true brooder (Koren and Danielssen, 1856; Fisher, 1940); that is, it was supposed to brood its young in the nidamental chamber (space between the supradorsal membrane and the aboral body wall) up to the young adult stage. Curiously enough, the embryology in general has never been described. This report presents information for the first time on embryonic and larval development. It also shows that this animal does not in fact brood.

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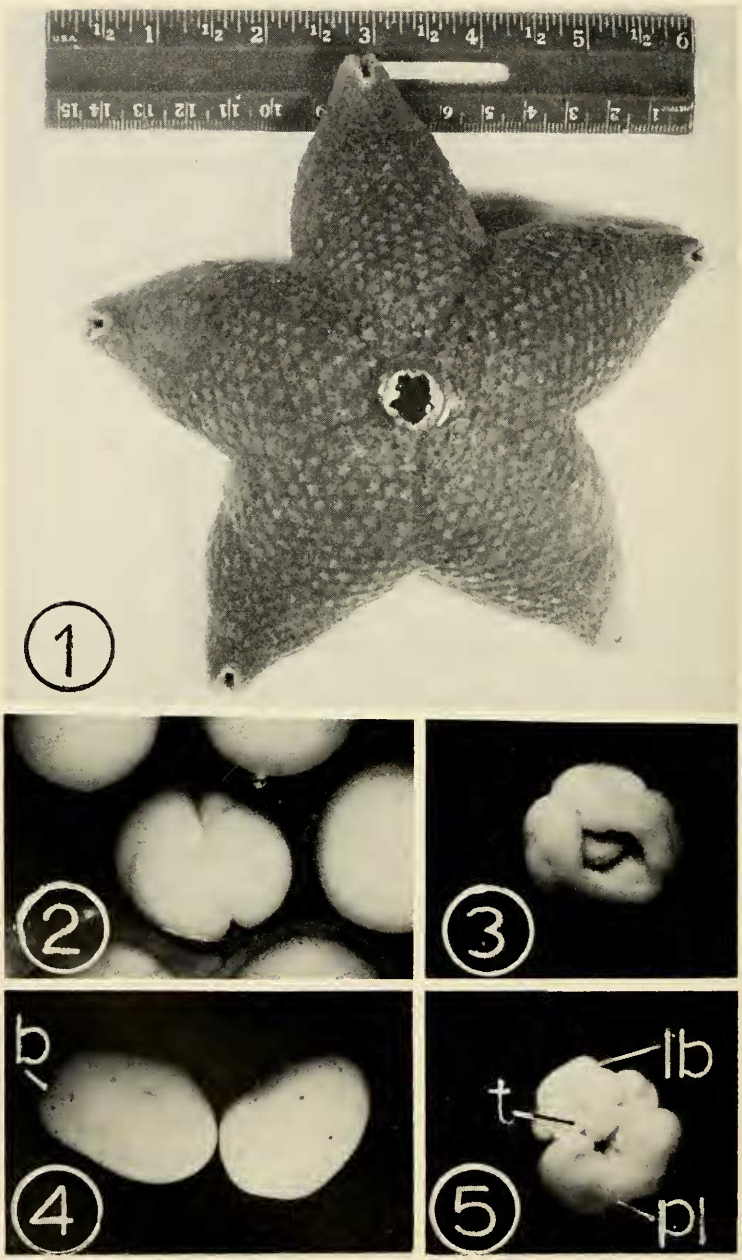
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This study was done in the summers of 1960 and 1963 at the Friday Harbor Laboratories, University of Washington. Approximately 20 animals were dredged from the Presidents Channel (101 fathoms deep) of the San Juan Archipelago, Washington, on July 13, 1960, but only six of them were brought to the laboratories. These animals were kept in a large wooden tank supplied with running sea water. Two females spawned the following morning after arrival. The eggs were pumped out through the osculum two or three at a time during each inflation, but infrequently a string of eggs (at least 20) were pumped out at one inflation. The eggs were transferred to a small aquarium of running sea water at a temperature of 10–13°C. and their development was observed under a stereomicroscope. Approximately 2 percent of such collected eggs underwent normal development; the rest either showed no sign of development at all or were arrested at early embryonic stages. No males were observed to spawn in the tank, but examination under a compound microscope demonstrated that a number of motile sperms were indeed attached to the eggs. So, apparently, the spawning of the males escaped observation. The inadequate supply of sperms might account for the low percentage of normal development. Furthermore, the differences between the laboratory and natural conditions cannot be underestimated on this aspect.

The spawned eggs floated on the surface of the water, were bright yellow or orange in color, and measured about 1.46 mm. in diameter. Each was surrounded by a coat of jelly which exhibited fine radiating channels. The fertilization membrane was visible beneath the jelly coat and the perivitelline space was comparatively small. The cleavage ranged from typical holoblastic and radial to an irregular type (fig. 2) and a wrinkled coeloblastula generally resulted. The blastula then gradually flattened along the animal-vegetal axis and soon hatched from the surrounding membranes. After hatching, the blastula swam by ciliary movement in a clockwise rotation along the animal-vegetal axis. Gastrulation was by embolic invagination at the flattened vegetal pole. The blastopore of the young gastrula was large and irregular in outline (fig. 3). The gastrula soon elongated along the animal-vegetal axis and transformed into a cone-shaped larva (fig. 4) which might be comparable to a bipinnaria. In

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FIGURE 1. Aboral view of a living animal, showing the central osculum where water is being pumped out. Note also the upward extension of the ambulacral groove at the tip of the arms.

FIGURE 2. Cleaving embryos; one is at four-cell stage. Note the jelly coat and fertilization membrane. 15×.

FIGURE 3. Gastrula, viewed from the vegetal pole, showing the large blastopore. 13×.

FIGURE 4. Cone-shaped larvae. b, region of closed blastopore. 13×.

FIGURE 5. Metamorphosing larva. 1b, larval body; pl, preoral lobe; t, tube feet. 13×.

the meantime the blastopore closed. Six days after fertilization, a circumferential groove occurred at the lower part of the cone-shaped larva and divided it into two distinct regions. The larger animal region became the preoral lobe and the small vegetal region became the larval body. As soon as the two parts were clearly distinguishable, five primordial arms of the young star appeared simultaneously in the vegetal part from the larval body and the first pair of tube feet soon appeared on each arm (fig. 5). The preoral lobe was completely absorbed when the young star had developed two pairs of tube feet in each arm, at which time the larva sank to the bottom of the aquarium and terminated its planktonic life. Immediately it started crawling with its tube feet and the process of metamorphosis was completed.

The most notable characteristics of the young star were the wrinkled epidermis of the aboral surface and the upward extension of the tips of the ambulacral grooves. No spines or ossicles were observed at this stage.

The chronological development at a temperature of 10° to 13°C. is summarized as follows:

1st day:	fertilization, cleavage.
2nd,	
3rd day:	blastulation and hatching.
4th day:	free swimming blastula, gastrulation, flattening along animal-vegetal axis.
5th day:	elongated along animal-vegetal axis, cone-shaped bipinnaria larva.
6th day:	preoral lobe and larval disk became distinguishable.
7th day:	onset of metamorphosis.
10th day:	arms of the young stars differentiated.
13th day:	first pair of tube feet developed.
16th day:	preoral lobe reduced in size.
25th day:	two pair of tube feet developed, preoral lobe almost absorbed; end of the planktonic life, young star crawled on the substratum with its tube feet.
30th day:	mouth opened.

Thus, the development of *Pteraster tesselatus* belongs to the type of direct development in the sense that no feeding larval stage is developed. The cone-shaped pelagic larva is comparable to a bipinnaria, but without a functional digestive system. In other words, the embryo has all its nutrition supplied by the yoke material in the egg.

The type of pelagic larva indicates indirectly that the present species does not brood its young. This point is further supported by the observations made in the summer of 1963. On August 30 of this year, 12 animals were dredged from the San Juan Channel (67 fathoms deep) and were dissected on the next day to

observe the condition of the gonads and to search for embryos in the nidamental chamber. If the animals were true brooders, one would expect to find embryos in the nidamental chamber of the spawned females. However, the results showed that among the 12 animals, 7 females (5 spawned, 2 nonspawned) and 5 males (all spawned), none of them possessed embryos in the nidamental chamber. This demonstrates directly that this animal is not a brooder and further indicates the breeding season of this species at San Juan Island is from early July to the end of August.

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